Journal of Environmental Management 169 (2016) 58–66

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Review

Tourism, biodiversity and protected areas – Review from northern Fennoscandia

Anne Tolvanen [a, *], Katja Kangas [b]

[a] Natural Resources Institute Finland and Department of Ecology, P.O. Box 413, FI-90014, University of Oulu, Finland
[b] Natural Resources Institute Finland, P.O. Box 413, FI-90014, University of Oulu, Finland

ARTICLE INFO

Article history:
Received 12 January 2015
Received in revised form
4 December 2015
Accepted 9 December 2015
Available online 22 December 2015

Keywords:
Alien species
Animal behavior
Nature protection
Recovery
Trampling
Tourist resort

ABSTRACT

Tourist numbers in northern Fennoscandia outweigh those in other northern boreal - arctic regions, which creates a specific need to evaluate the impacts of tourism. This review 1) identifies patterns and trends in the vegetation and wildlife of northern Fennoscandian terrestrial ecosystems as a consequence of tourism and recreation, 2) discusses the implications of findings in terms of the intensity, area and magnitude of impacts, changing climate and management needs under increasing tourist pressure, and 3) identifies research gaps. The reviewed studies show negative environmental and biodiversity impacts that are most pronounced near tourist resorts. The most sensitive plants, birds and mammals decline or disappear from the disturbed sites, and the species composition shifts from 'wild' species to cultural and human associated species. There is little research on the spread of alien species, but the few examples show that alien species can be promoted by tourism activities. Impacts of the use of motorized vehicles have not been widely studied either, despite the extensive track network which can cause disturbance to wildlife. The integrated impacts of tourism and climate change on the vegetation and wildlife was not addressed directly in any of the reviewed studies. In addition, little research has been done on carrying out restoration at tourist areas. Scientific research on these topics is needed to prevent, minimize or restore the most negative ecological impacts of tourism and recreation.

Contents

1. Introduction

Tourism and recreation are considered one of the major threats

* Corresponding author.
E-mail address: anne.tolvanen@luke.fi (A. Tolvanen).

http://dx.doi.org/10.1016/j.jenvman.2015.12.011
0301-4797/

to wilderness ecosystems and a frequent threat to threatened species (Cole and Landres, 1996; Ballantyne and Pickering, 2013; Rankin et al., 2015). The negative biophysical impacts of tourism and recreation have been known about for almost a century (Pickering et al., 2010). Tourism and recreation are known to affect vegetation, soil and wildlife directly or indirectly (Liddle, 1997; Hammit and Cole, 1998; Buckley, 2004). Tourism can also lead to new biological invasions (Williams et al., 2010), which represent the second most significant cause of species extinction worldwide, the first being habitat destruction (IUCN, 2011). Cold ecosystems such as arctic and alpine areas are especially sensitive to disturbance caused by tourism and recreation, since the vegetation regeneration rate is slow (Forbes et al., 2001; Willard et al., 2007). Climate warming is predicted to be more pronounced in arctic regions than on average across the globe (IPCC, 2013). The increasing tourism pressure together with climate warming may enhance the biodiversity changes in arctic ecosystems through, for example, the increase of alien species, changed species interactions and increased regeneration rates of disturbance tolerant species.

The importance of nature as a tourist attraction has increased visitor numbers in protected areas globally (Eagles, 2007; Balmford et al., 2009; Siikamäki et al., 2015). Safeguarding of valuable species and habitats is generally the principal purpose of nature protection, but the heavy increase in tourist numbers poses a risk that the biodiversity values on which the protection relies will be degraded. According to statistics from recent decades, tourist numbers in northern Fennoscandia surpass those in arctic Canada and the US, despite its considerably smaller area (*e.g.* Mason, 1998; Hall and Saarinen, 2010). For example, in Finnish national parks, visitor numbers increased on average 6.5-fold between 1990 and 2008 (Kangas, 2009). The development of tourism and recreation has been largely shaped by two factors in northern Fennoscandia: the right of public access which allows *e.g.* hiking, skiing, horse riding and short-term camping (*e.g.* Forbes et al., 2004; Tolvanen et al., 2005) and the good accessibility and well-developed road network (Lundgren, 1995). The high tourist pressure in the sensitive environment creates a specific need to evaluate the impacts of tourism in order to manage tourism at a sustainable level.

In this review we 1) identify patterns and trends in the biodiversity of northern Fennoscandian ecosystems as a consequence of tourism and recreation, 2) discuss the findings in terms of the intensity, impact area and magnitude of impacts, changing climate and management needs under increasing tourist pressure, and 3) identify research gaps. The focus is on terrestrial ecosystems, and the biodiversity impacts are discussed in terms of the plant and wildlife communities and alien species.

2. Methods

We searched for ecological impact studies presenting original data using Google Scholar. The main keywords were 'tourism' or 'recreation', and later also 'camping', 'disturbance', 'path', 'ski', 'track' and 'trail', which we used in combination with the terms 'alien species', 'animal', 'avian' 'biodiversity', 'bird', 'mammal', 'plant', 'soil', 'trampling' and 'wildlife'. We selected the northern Fennoscandian region using the countries 'Finland', 'Norway', 'Svalbard' (Norwegian territory) or 'Sweden', and from these we chose the studies carried out in northern boreal, subalpine, alpine, subarctic or arctic regions. Reference lists of new articles were also searched. In cases where scientific literature was not available in English, gray literature was also searched. Studies of the physical development of trails and the regeneration of vegetation during scientific expeditions (Pounder, 1985; Gellatly et al., 1986a; Wielgolaski, 1998) and an as yet unpublished long-term study on military camping (Ylisirniö and Allén unpublished data) were included in the review, although they do not investigate tourism and recreation impacts *per se*. The information from these studies is however directly applicable to tourism and recreation.

We found 40 studies, of which 18 were on vegetation and soils (for example the development of trails after trampling), 7 on birds, 1 on birds and mammals, and 14 on mammals. We list the studies, study aims, main findings and study locations in Table 1. Alien species lists (Liška and Soldán, 2004; Elven, 2015) and an overview of alien species without original data (Coulson, 2012) were not listed in Table 1. The term 'tourist resort' was used for ski resorts, tourist resorts and holiday cabin concentrations.

We arranged the six studied tourism and recreation types, *i.e.* hiking, skiing, horse riding, camping, snowmobiling and tourist resorts, according to their intensity of impact (i.e. amount of impact per unit area), as estimated from the reviewed studies. The assessment was based principally on the direct and indirect disturbance on vegetation and soils, as these are well documented. The intensity of impact on wildlife is more difficult to observe and measure, because they are not stationary and because of difficulties separating the impacts of recreation from the impacts of confounding variables (Hammit and Cole, 1998).

We aimed to calculate the magnitude of the six recreation types by multiplying the intensity of impact by their impact area. Since there are no consistent data on the impact areas by recreation types throughout northern Fennoscandia, we estimated the area only for northern Finland, where there is abundant information in public databases and scientific and gray literature. The magnitudes are therefore not directly applicable outside Finland. The total lengths of hiking and skiing tracks were obtained from Excursionmap.fi (2015), the total number of campsites and the length of snowmobile tracks from Wilderness licences and experiences (2015), and the number of tourist resorts from Kaisanlahti-Jokimäki et al. (2008). To calculate the impact areas, total hiking trail and skiing track lengths were multiplied with their mean widths, obtained from Törn et al. (2009), and total snowmobile track lengths with their mean widths obtained from Vuorela (2014). The number of campsites was multiplied by the mean campsite area, obtained from Kangas et al. (2007) and Tukiainen (2010), and the number of tourist resorts by the mean tourist resort area obtained from Kaisanlahti-Jokimäki et al. (2008). Finally, we calculated the relative magnitudes using rank order scales from 1 to 6 for both the intensity and the impact area of the six recreation types. There was no public information on the length of horse trails, as the trail network is underdeveloped in Finland (The Equestrian Federation of Finland (2015)). Hence we assumed that the impact area of horse trails is lower than that of the other recreation types and gave them the lowest rank of 1.

3. Patterns and trends in northern environments as a consequence of tourism and recreation

3.1. Vegetation and soils

The direct impacts of recreational trampling are well documented in northern Fennoscandia (Table 1). The most dramatic vegetation changes occur at low trampling intensities (Emanuelsson, 1984; Gellatly et al., 1986b; Tolvanen et al., 2001). After a certain threshold has been passed, the loss of vegetation is total, but the threshold varies between habitats (Emanuelsson, 1984; Pounder, 1985; Gellatly et al., 1986b; Tolvanen et al., 2001). After short-term trampling, the vegetation recovery can be rapid, if the trampling pressure is removed (Törn et al., 2006), whereas long-term trampling changes the physical and hydrological properties of the soil (Gellatly et al., 1986a; Törn et al., 2009). Severely degraded habitats can need a substantial length of time to recover.

Table 1
Summary of the reviewed studies.

Study targets and aims	Core findings	Location	Reference
Vegetation and soil			
Population and lower level impacts			
Short-term experimental trampling	50% decrease in the density of dwarf shrubs after 75–200 passes.	Subarctic Finland	Tolvanen et al. (2001)
Community and lower level impacts			
Hiking and experimental trampling	Loss of species richness and biomass. Dry grassland more tolerant than moist grassland and lichen-dominated heathland.	Boreal Norway	Arnesen (1999a)
15 year vegetation recovery after experimental trampling	Lower species richness and vegetation cover compared to untrampled vegetation.	Boreal Norway	Arnesen (1999b)
Experimental trampling, long-term effects of trails	50% decrease in vegetation cover after 30, 60 and 70 passes in fens, heaths and mires, respectively.	Subalpine Sweden	Emanuelsson (1984)
Short-term experimental trampling	30% decrease in plant cover after 200 passes.	Subalpine Norway	Gellatly et al. (1986b)
Campsite disturbance	Disturbance zones, graminoids most tolerant to trampling.	Boreal and subarctic Finland	Hoogesteger (1976)
Campsite disturbance effects	Graminoids tolerant to trampling, dwarf shrubs and lichens least tolerant.	Subarctic Sweden	Hoogesteger (1984)
Campsite disturbance effects	Disturbance zones. Shrubs, mosses and lichens disappear from the most disturbed sites.	Boreal and subarctic Finland	Kangas et al. (2007)
Short-term experimental trampling	Immediate decrease of vascular plants, delayed decrease of bryophytes. Rapid recovery after cessation of trampling.	Subarctic Finland	Törn et al. (2006)
Ecosystem and lower level impacts			
Short-term trampling effects	Increase in soil compaction and bulk density.	Arctic Norway	Gellatly et al. (1986a)
Ski run treatment effects	Although the germination of alien species is favored by ski run management, they cannot establish in neighboring forest.	Boreal Finland	Kangas et al. (2009)
Footpath development	Critical threshold for plant survival 4500 -17 000 tramplings.	Arctic Norway	Pounder (1985)
Soil nutrient status	Most of the ski-run area covered with degraded bare soil with insuffcient amount of nutrients and OM.	Subarctic Finland	Ruth-Balaganskaya and Myllynen-Malinen (2000)
Hiking, skiing and horse riding effects	Horse riding has greatest impact on vegetation through damage and introduction of alien species. Hiking more detrimental than skiing. Relatively dry forest most tolerant to trampling.	Boreal and subarctic Finland	Törn et al. (2009)
Horse riding and experimental horse riding effects	Horse promotes the establishment of alien species.	Boreal Finland	Törn et al. (2010)
Quantification of propagule transport via travelers' footwear	On average 3.9 seeds per traveler transported, *Poaceae* having the highest diversity and seed number.	High arctic Svalbard	Ware et al. (2012)
22 years of recovery after intensive ecological study	Trails at nutrient rich sites recover most rapidly. Only bryophytes recovered fully. The initial recovery of graminoids has stopped.	Alpine Norway	Wielgolaski (1998)
Recovery of military camps 64 years after use	Still thinner humus layer at disturbed sites, permanent shift from heath vegetation towards graminoid dominated vegetation.	Subarctic Finland	Ylisirniö and Allén (2015, unpubl.)
Wildlife			
Individual level impacts			
Reaction to humans	Mean escape distance of Pink-footed geese (*Anser brachyrhynchus*) 1717 m, brent geese (*Branta leucopsis*) 620 m and barnacle geese (*B. bernicla hrota*) 330 m.	Svalbard	Madsen et al. (2009)
Reaction to snow mobiles	Mean alert distance of Polar bear (*Ursus maritimus*) 1164 m, response distance 843 m. Females with cubs respond at longer distances.	Svalbard	Andersen and Aars (2008)
Reaction to direct provocation by snow mobiles	Minimum reaction distance of Svalbard reindeer (*Rangifer tarandus platyrhynchus*) 640 m, disturbance distance 410 m. Increase in daily energy expenditure and decrease the grazing time.	Svalbard	Tyler (1991)
Population and lower level impacts			
Impact of holiday cabins	Lowered breeding success of Willow ptarmigan (*Lagopus lagopus*) up to 1.5 km from holiday cabins through the nest predation by corvids.	South-central Norway	Støen et al. (2010)
Impact of tourist resorts	Inceased densities of mountain hare (*Lepus timidus*) and mustelids near tourist resorts.	Northern Finland	Ukkola et al. (2007)
Impact of human disturbance and recreational activities	Tendency for less bear (*Ursus arctos*) observations near holiday cabins.	South-central Norway	Elgmork (1978)
Impact of holiday cabin construction	The number of bear observations decreased during 30-year period.	South-central Norway	Elgmork (1983)
Habitat use in relation to tourist resorts and towns	Bears avoid tourist resorts. Females and older individuals most sensitive to disturbance, locating mostly beyond 10 km distance.	South-central Sweden south-eastern Norway	Nellemann et al. (2007)
Semi-domesticated reindeer (Rangifer tarandus tarandus)			
Distribution around tourist resorts	Decreased densities near tourist resorts in birch and pine forests, but not on alpine hill-tops. In summer, females more sensitive to disturbance than males.	Northern Finland	Helle and Särkelä (1993)
Distribution around tourist resorts	Decreased densities near tourist resorts. Increased tolerance: reindeer density increased in 14 years despite the doubling of visitor numbers.	Northern Finland	Helle et al. 2012
Habitat selection under insect harassment and human disturbance	Tendency for higher reindeer densities near trails. Avoidance of insects overrides impacts of human disturbance.	Western Sweden	Skarin et al. 2004
Habitat selection of reindeer during summer season	Hiking trails have no impact on habitat selection. Avoidance of areas with houses and holiday cabins during early summer.	Western and northern Sweden	Skarin et al. 2008
Avoidance behavior of calving reindeer near tourist resorts.	Decreased densities near tourist resorts. Females with calves more sensitive to disturbance than males.	Northern Norway	Vistnes and Nellemann (2001)
Wild reindeer (Rangifer tarandus tarandus)			
Avoidance behavior at high-altitude tourist resorts during winter	Maternal reindeer avoided a 10 km zone around the resort, bulls and yearlings a 5 –10 km zone. Overgrazing further from the resort.	South-central Norway	Nellemann et al. (2000)

Table 1 (*continued*)

Study targets and aims	Core findings	Location	Reference
Distribution around power lines, roads and resorts during winter	Decreased densities near tourist resorts. Females and calves more sensitive to disturbance than males.	South-central Norway	Nellemann et al. (2001)
Effects of tourist resorts and removal of tourism facilities on the reindeer	Decreased densities at tourist resorts. No observed habituation during the 20-year period. Restoration of the access to historic habitat brought reindeer back to the area.	South-central Norway	Nellemann et al. (2010)
Distribution around tourist resorts	Tendency to avoid tourist resorts and major roads up to 5 km and hiking trails up to 2.5 km.	Southern Norway	Vistnes et al. (2008)
Community and lower level impacts			
Recreational gradient from tourist resorts to forests	Higher abundances of human-associated birds, corvid species, cavity and building nesters, and edge species in tourist resorts.	Northern Finland	Huhta and Sulkava (2014)
Species composition in towns, tourist resorts and forests	Abundance of human-associated bird species higher in tourist resorts than forests.	Northern Finland	Jokimäki et al. (2007)
Nest predation risk and abundance from towns via tourist resorts to forests	Artificial ground-nest predation and the abundance of corvids increase with increasing urbanization.	Northern Finland	Kaisanlahti-Jokimäki et al. (2008)
Golden Eagle (*Aquila chrysaetos*) around tourist resorts	Nearest occupied nest on average 9.9 km fron ski resort and nearest successful nesting 10.3 km.	Northern Finland	Kaisanlahti-Jokimäki et al. (2012)
Species richness, composition and bird occurrence around hiking trails	Open-cup nesters nesting on the ground more sensitive than open-cup nesters on trees and shrubs. No impact on species richness or cavity nesting birds.	Northern Finland	Kangas et al. (2010)

A 22-year study in alpine Norway shows that despite the recovery of bryophytes after the end of trampling and scientific harvesting, the cover of vascular plants had still not reached the level of undisturbed vegetation (Wielgolaski, 1998). Monitoring of the recovery of military camps in subarctic Finland 64 years after their abandonment shows no ecological recovery in the humus layer or in the original vegetation. Instead, there is a permanent shift to trampling tolerant plant communities dominated by graminoids (Ylisirniö and Allén unpublished data), which is the first time in northern Fennoscandia that a permanent vegetation shift has been recorded as a consequence of trampling.

The vegetation type reflects the tolerance toward disturbances. The habitats most sensitive to trampling are the wettest habitats such as fens (Emanuelsson, 1984; Arnesen, 1999b) and the driest habitats such as dry heaths (Wielgolaski, 1998; Arnesen, 1999a; Tolvanen et al., 2001) and dry heath forests (Törn et al., 2009). In fens, trampling may expose the peat (Arnesen, 1999b), and in dry habitats the mineral soil is exposed quickly due to the trampling of the thin organic layer (Törn et al., 2009). In the dry open subalpine environment, the easy access to off-trail recreation also leads to the rapid expansion of the degradation (Kangas et al., 2007; Törn et al., 2009). Natural environments fairly tolerant to trampling include relatively dry grasslands, due to the dominance of trampling tolerant graminoids (Arnesen, 1999a), relatively dry boreal forests, due to the dominance of *Vaccinium* dwarf shrubs (Törn et al., 2009), and subalpine meadows, due to the rapid regeneration of the vegetation in the nutrient-rich environment (Emanuelsson, 1984; Wielgolaski, 1998; Tolvanen et al., 2001). Secondary habitats dominated by fast-growing graminoids are more tolerant to trampling than are natural habitats, as they are outcomes of earlier disturbances (Kangas et al., 2007).

The impact of tourism and recreation on the vegetation depends on the recreation type. Hiking, cross country skiing, camping and horse riding are popular recreation activities in the protected areas and mountain environments of northern Fennoscandia (Heberlein et al., 2002; Wall Reinius and Fredman, 2007; Zachrisson, 2008; Haukeland, 2011a). A comparison of the impacts of hiking, cross country skiing and horse riding in the Pallas-Yllästunturi and Oulanka national parks in Finland shows that horses caused a similar trampling impact to that of hiking, even though the number of annual hikers was 150 times that of horse riders (Törn et al., 2009). Cross country skiing had the weakest trampling effect, due to the protection of the soil by the snow cover. Nevertheless, the secondary impacts of skiing were greater than those of hiking, due to the clear cutting of skiing tracks in the forests, which favored the succession of plant species typical of open habitats, and due to the compaction of the snow, which delayed the snowmelt (Törn et al., 2009). Camping studies carried out in Finland and Sweden reveal that camping creates vegetation zones of varying degradation levels, whereby the most degraded zone lacks vegetation almost completely and the intermediate zones are dominated by graminoids (Hoogesteger, 1976, 1984; Kangas et al., 2007).

There are only two studies on the soil and vegetation impacts of ski run construction in northern Fennoscandia, from Ylläs and Ruka in Finland (Ruth-Balaganskaya and Myllynen-Malinen, 2000; Kangas et al., 2009, respectively), which are among the largest tourist resorts in the region. Machine grading was observed to remove the ground vegetation and the top layer of the soil and affect the structure, nutrient levels and hydrological function of the soil (Ruth-Balaganskaya and Myllynen-Malinen, 2000). The vegetation sown on the ski slopes required fertilization, which is assumed to increase the nutrient runoff from the slopes (Kangas et al., 2009). A survey of the water quality of the lakes near to tourist resorts showed that the quality was quite similar to that of lakes under the impact of agriculture and forestry (Kangas et al., 2012, not a biodiversity study and therefore not shown in Table 1).

3.2. Alien plant species

Three studies focus on the spread of alien plant seed (Kangas et al., 2007; Törn et al., 2009; Ware et al., 2012) and two studies provide information on the establishment of alien plants in boreal forests (Kangas et al., 2007; Törn et al., 2009). The experimental addition of horse manure introduced seeds of graminoids and forbs which were absent elsewhere in the dwarf-shrub dominated forests of Oulanka National Park (Törn et al., 2010). Soil disturbance enhances seed germination, and over 20 weed species were found along recreational horse resting areas and horse trails (Törn et al., 2009). Feeding of horses with hay that included the seeds of grasses and forbs was assumed to be a significant reason for the spread of alien species. At tourist resorts, the seeds of alien species are intentionally spread on ski slopes for the purposes of revegetation. They may germinate in neighboring forests, provided that soil disturbance or fertilization continues (Kangas et al., 2009). The campsite survey conducted in the Pallas-Yllästunturi national park showed that alien plant species grow mostly in the disturbed areas of the campsites (Kangas et al., 2007). However, alien species were not observed to have established themselves in undisturbed boreal forests in any of these studies. In the high arctic Svalbard, on average 3.9 seeds per visitor belonging to 53 species, were observed to be imported on the footwear of travelers (Ware et al., 2012). Eight of the families, such as *Poaceae*, are among the most invasive worldwide. According to the overview by Coulson (2012, and references therein, not in Table 1), approximately 60 species of alien vascular plants have been recorded in the settlements of Svalbard. Of the recorded species, 28–37 are believed to be firmly established but do not seem to be spreading far beyond the point of establishment.

3.3. *Wildlife*

Tourism and recreation impact studies on wildlife in Fennoscandia are focused on birds and a few large mammal species (Table 1). Two studies indicate that current visitor levels have not caused substantial changes in bird communities in protected areas of northern Finland (Kangas et al., 2010; Huhta and Sulkava, 2014). Although open-cup nesters nesting on the ground showed a negative response to the number of visits at hiking trails, the species richness remained unaffected, as sensitive species were apparently replaced by generalist species (Kangas et al., 2010). Similarly, another study in northern Finland reveals that the proportion of ground nesters is higher in forests than in tourist destinations, while cavity-nesting species show the opposite trend (Kaisanlahti-Jokimäki et al., 2012). Ground-nesting species are affected by the direct disturbance caused by visitors (Madsen et al., 2009), increased nest predation (Madsen et al., 2009; Støen et al., 2010; Kaisanlahti-Jokimäki et al., 2012), and the decreased cover of the nesting and foraging substrate due to the construction of the tourism infrastructure, whereas tourism infrastructures provide shelter and nesting sites for cavity-nesting birds (Kaisanlahti-Jokimäki et al., 2012; Huhta and Sulkava, 2014).

Three studies investigate the immediate reaction of wildlife to disturbance (Tyler, 1991; Andersen and Aars, 2008 Madsen et al., 2009). In Svalbard, the behavioral responses of three goose species to disturbance caused by human on foot were estimated using alert distances, escape length distances and the duration of escape flights (Madsen et al., 2009). The pink footed goose (*Anser brachyrhynchus*) was observed to be more vulnerable to human disturbance than the other species and it responded from longer ranges and took flight at longer distances, which caused increased nest loss by avian predators (Madsen et al., 2009). The flight behavior can also increase the daily energy expenditure and decrease the feeding time, as indicated by a study on flight responses caused by snowmobile disturbance on Svalbard reindeer (Tyler, 1991). In addition to the variation of sensitivity to disturbance between species (Madsen et al., 2009), age and sex can affect the tolerance of individuals (*e.g.* Andersen and Aars, 2008). For example, female polar bears (*Ursus maritimus*) with cubs and single medium-sized bears showed stronger responses from greater distance to snowmobiles than did adult males and lone adult females (Andersen and Aars, 2008). In addition, female wild reindeer (*Rangifer tarandus tarandus*) (Nellemann et al., 2000, 2001) as well as semi-domesticated reindeer (*R. tarandus tarandus*) (Helle and Särkelä, 1993; Vistnes and Nellemann, 2001; Helle et al., 2012) are more sensitive to disturbance than males.

Raptors are also known to avoid nesting in areas with human disturbance. Kaisanlahti-Jokimäki et al. (2008) found that there were fewer golden eagle (*Aquila chrysaetos*) territories near tourist resorts than in undisturbed areas in northern Finland. Avoidance of tourist resorts has also been observed among large mammals with wide home ranges. Tourist resorts and holiday cabin construction was observed to decrease the occurrence of brown bear (*Ursus arctos*) in Norway (Elgmork, 1978, 1983; Nellemann et al., 2007). Semi-domesticated reindeer (*R. tarandus tarandus*) (Helle and Särkelä, 1993; Skarin et al., 2008; Helle et al., 2012; Vistnes and Nellemann, 2001) and wild reindeer (*R. tarandus tarandus*) (Nellemann et al., 2000, 2001, 2010; Vistnes et al., 2008) were also found to avoid tourist resorts. However, disturbance caused by hiking trails has not been found to affect the habitat selection of semi-domesticated reindeer in Sweden (Skarin et al., 2004, 2008). The avoidance of insect harassment and warm weather may override the impacts of disturbance by hikers, and there is a possibility that the reindeer have become habituated to humans (Skarin et al., 2004, 2008). Helle et al. (2012) observed an increased tolerance of ski resorts by semi-domesticated reindeer during a 14-year observation period, probably due to the improved channeling of outdoor activities, changes in reindeer herd-management and frequent contacts with humans. In contrast to the semi-domesticated reindeer, wild reindeer were not observed to show habituation to tourist resorts in a 20-year study in Norway (Nellemann et al., 2010). Nevertheless, restoring the access to their historic habitat by removing ski trails and tourist cabins drew the reindeer back to the area.

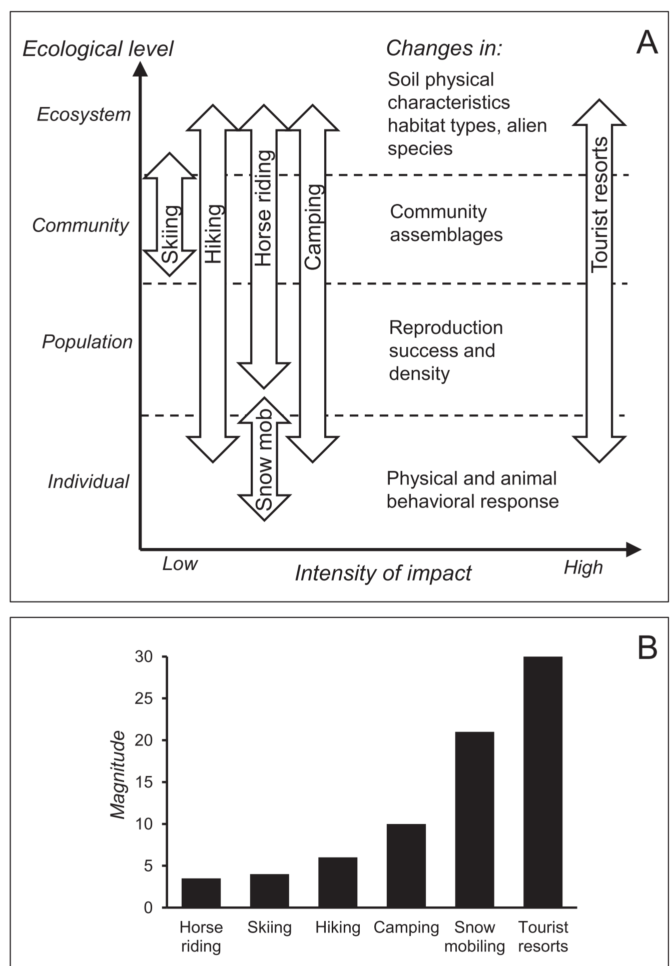

Fig. 1. Ecological levels and the intensity of impacts of six tourism and recreation types in northern Fennoscandia (A). Relative magnitude (rank intensity × rank impact area) of different recreation types evaluated for northern Finland (B).

Some wildlife species can benefit from human impact in tourist resorts, and high numbers of these 'urban species,' *i.e.* human associated species, may increase the species richness above the level observed in surrounding natural habitats (Kaisanlahti-Jokimäki et al., 2012; Huhta and Sulkava, 2014). Urban species benefit, for example, from increased numbers of nesting sites and new food resources through human waste and winter feeding. Common urban birds such as the blue tit (*Parus caeruleus*), house sparrow (*Passer domesticus*) and corvids (*Corvidae*) were observed to increase in tourist resorts in Finnish Lapland (Jokimäki et al., 2007). The increase of corvid species near human resorts can increase nest predation, as was found with an artificial ground nest predation experiment in Finland (Kaisanlahti-Jokimäki et al., 2012) as well as in Norway (Støen et al., 2010). Densities of mountain hare (*Lepus timidus*) and mustelids were also found to increase near tourist resorts (Ukkola et al., 2007).

4. Implications of findings

4.1. Levels, intensity and magnitude of tourism and recreation impacts

The reviewed studies show negative environmental and biodiversity impacts of tourism and recreation and generally support earlier findings from many other regions (Liddle, 1997; Buckley, 2004; Monz et al., 2013). At the lowest ecological level, *i.e.* the individual level, the impacts concern changes in physical reactions and/or animal behavioral responses (Fig. 1a). These changes are reflected at the population level in changed reproduction success and population densities, which are thereafter seen as changes in community assemblages due to the increase of tolerant species and decrease of sensitive species. Ecosystem-level impacts are seen as changes in the physical and chemical characteristics of the soil, the transformation of habitat types and the invasion of alien species. Hiking, camping and tourist resorts were observed to cause changes at all ecological levels, whereas the number of studies on the impacts of cross country skiing, horse riding and snowmobiling were apparently too few to show impacts at all levels.

The impacts of skiing were regarded as less intensive than those of hiking due to the low direct impact on the vegetation and soils (Fig. 1a). Hiking causes trail erosion and may have a long-term impact on the vegetation, but the changes are restricted to a narrow area. Horse riding was regarded to have a greater impact on the vegetation and soils than hiking due to the greater trail erosion effect and the increased risk of the introduction of alien species. There are no studies on the impact on snowmobiles on the vegetation in northern Fennoscandia. Studies from northern America show that snowmobiles appear to have similar but considerably stronger impacts as skiing through the compaction of snow and delayed snow melt, and at least locally a stronger damage to plants and soils than hiking, since snowmobiling may be carried out under conditions with little snow (*e.g.* Greller et al., 1974). Snowmobiling was therefore regarded as equally intensive as horse riding, but this was a rough estimate. Camping was regarded to have greater impacts than horse riding and snowmobiling due to the large-scale vegetation change, erosion and increased amounts of alien species around campsites. Tourist resorts were regarded to have the most pronounced impacts on the environment, vegetation and wildlife, and they changed wilderness environments to urban-like resorts and promoted the spread of invasive alien species.

The evaluation of the magnitude of impacts requires the estimation of both the intensity and the impact area (Cole, 2004). Concerning the example in northern Finland (11 450 km^2 total area), where the relative magnitudes could be calculated, the total area of snowmobile tracks is 56 km^2, tourist resorts 25 km^2, skiing tracks 9 km^2, hiking trails 1 km^2 and campsites 0.01 km^2. This indicates that the area under tourism and recreational use is marginal, and hence the direct impacts on the vegetation and environment are still quite minor. Nevertheless, the impact area may be multiplied for the wildlife, since the most sensitive species avoid tourist resorts for up to a 10 km distance (Table 1, Kaisanlahti-Jokimäki et al., 2008; Nellemann et al., 2007). Fig. 1b shows that the relative magnitude of tourist resorts overrules all other forms of recreation. A rough estimate concerning the most sensitive species with 10 km avoidance indicates that the total impact area of tourist resorts would increase from 25 km^2 to above 4000 km^2. Since other recreation forms such as skiing, hiking and snowmobiling often concentrate around tourist resorts, this further emphasizes their impact on the environment. Snowmobiling had a surprisingly high magnitude of impact, which was due to the extensive snowmobile track network throughout northern Finland. The impact area of snow mobiles is difficult to estimate for the wildlife, however, since the disturbance caused by snowmobiles is not continuous.

4.2. Climate change

The integrated impacts of tourism and climate change on the vegetation and/or wildlife were not addressed directly in any of the reviewed studies, although potential impacts were discussed in three studies on the spread of alien plant seeds. In general, climate change has triggered a remarkable number of tourism studies, which have mostly discussed the ability of the tourism industry and human societies to adapt to risks caused by climate change (see *e.g.* Weaver, 2011; Scott and Becken, 2014 and the references therein). In northern Fennoscandia, these studies are related to threats to winter tourism (Moen and Fredman, 2007; Kietäväinen and Tuulentie, 2013), but not to potential environmental and ecological impacts. The increasing tourism pressure together with climate warming may enhance the ecological changes through, for example, the increase of alien species under warmer conditions, changed species interactions and enhanced plant regeneration rates through the increase of tolerant species.

Fennoscandia may not appear to be among the most suitable environments for alien species due to its harsh temperature conditions that limit the germination and seedling growth. The total number of alien plants is still low, and they are confined to, for example, settlements and their close surroundings, mining areas and roads and railways (*e.g.* Liška and Soldán, 2004; Elven, 2015). The two studies from northern Fennoscandia (Törn et al., 2010; Ware et al., 2012) show that the cold environment does not, however, protect the area from species invasions, if, for example, germinable plant seed are imported by people or animals. Members of the *Poaceae* family (grasses), being among the most invasive worldwide, have been commonly observed among the imported seeds in arctic (Ware et al., 2012) and antarctic (Chown et al., 2012) regions. Being disturbance tolerant species with a rapid regeneration capacity, there is a risk that these species could continue to spread in tourist resorts and along trail networks, if disturbance continues and intensifies along with increasing tourist numbers. In the third Fennoscandian study there was no indication that the alien species sown during the revegetation of tourist resort had established in the native vegetation (Kangas et al., 2009). The lag-phase between the introduction and the successful spread and impact of alien species can take decades, however. For example, invasive species originating from the revegetation practices of tourist resorts were observed to establish in native vegetation in the Australian Alps (McDougall et al., 2005; Pickering et al., 2007).

There were no studies on the combined impacts of tourism and climate change on species interactions and regeneration rates. Long-term studies from subarctic and arctic environments, as well as from northern Fennoscandia, indicate that warming increases the amount of deciduous shrubs (Walker et al., 2006; Elmendorf et al., 2012a, b) and results in greater rates of gross ecosystem production (Ylänne et al., 2015). Since deciduous dwarf shrubs are moderately tolerant to disturbances and the ecosystem production is expected to increase, this indicates that the tolerance of vegetation to disturbance caused by tourism may increase.

4.3. Research gaps

Many research gaps were identified based on the reviewed studies. Vegetation and soil impact studies have been principally short-term trampling studies, which does not give information on the impacts of prolonged disturbances or on long-term recovery processes. Long-term monitoring is also needed to give information on the impacts of tourism on wildlife populations, which occur, for example, through their movement to suboptimal habitats, increased energy consumption and decreased time for feeding, and increased nest predation. Vegetation recovery studies concentrate on community-level changes, whereas the impact of tourism and tourist behavior on threatened plants has not been studied. Trampling, collecting of conspicuous plants and clearing of vegetation for construction are potential risks posed by tourism toward threatened species (Kelly et al., 2003). For example in Finnish national parks, hiking trails are located in the same areas as threatened species (Siikamäki et al., 2015), which exposes the species to recreation impacts. The research on mammals concentrates on a few large charismatic wildlife species such as the brown bear, polar bear and reindeer, whereas little is known about the responses of smaller mammals and threatened species such as the wolf and wolverine. Apart from the two studies on snowmobiles (Tyler, 1991; Andersen and Aars, 2008), the impacts of motorized vehicles have received surprisingly little attention in northern Fennoscandia in relation to their increasing popularity and rapidly developing track network. More information is also needed on the combined ecological impacts of tourism and climate change, especially on the spread of alien species, changes in species composition and animal behavior, and changes in the regeneration rate, to evaluate the potential of northern Fennoscandian ecosystems to withstand tourism under a warming climate. Apart from one study considering the restoration of the access to historic reindeer habitats (Nellemann et al., 2010), ecological restoration research has not been combined with tourism studies, although active ecological restoration is an important means of enhancing the biodiversity in habitats degraded by human activities (Rey Benayas et al., 2009).

4.4. Management implications in protected areas and tourist resorts

The increase in tourist numbers in northern Fennoscandia is related to the development of both protected areas and large tourist resorts. For example in Finnish national parks, visitor numbers increased on average 6.5-fold between 1990 and 2008 (Kangas, 2009). At the same time, visitor numbers doubled in terms of overnight stays between 1996 and 2006 in Finnish Lapland (Tyrväinen and Järviluoma, 2009), and the present aim is to further double the annual visitor rates by 2020 (Tyrväinen et al., 2014). In Swedish Lapland and protected areas in Norway, tourism development has not involved mass tourism to the same extent, although the need to boost the economy through international tourism has been recently acknowledged (Haukeland, 2011a; Hållbar destinationsutveckling … 2014).

The scientific data provide information that can be used to prevent, minimize or restore the most negative ecological impacts of tourism. For example, information on the degradation and recovery rates of the vegetation and soils can be used for planning trails and campsites, and for planning restoration and revegetation measures. Studies provide information on sensitive species, habitats and seasons, considering, for example, the nesting period of birds. The information can be used to minimize recreational use of sensitive habitats and during critical seasons (Zoning, *e.g.* Eagles et al., 2002). The information on visually observable variables such as trail physical characteristics and key plant and animal species can be integrated into existing planning and management frameworks as ecological indicators which show the short-term and long-term development of the environment and biodiversity under tourist pressure. Several management frameworks have been applied to promote sustainable tourism in northern Fennoscandia, for example the Limits of Acceptable Change (Stankey et al., 1985) in Finland (Heinonen, 2007; Siikamäki and Kangas, 2009), the Recreation Opportunity Spectrum (Clark and Stankey, 1979; Brown et al., 1978) in Sweden and an adaptation of both of these in Norway (Haukeland, 2011b). Many indicator systems suitable for these frameworks have already been developed (Jokimäki and Kaisanlahti-Jokimäki, 2007; Huhta and Sulkava, 2014; Uusitalo and Sarala 2015), but there are only a few examples (*e.g.* Siikamäki and Kangas, 2009) where they have been used in practice.

The focus of the present paper was on observed negative ecological impacts. It must be noted that tourism may also have indirect positive impacts. For example, biodiversity values are important tourist attractions in Finland (Puustinen et al., 2009, Lyon et al., 2012, Siikamäki et al., 2015), and protection status has been observed to act as a marker to tourists in Sweden (Wall Reinius and Fredman, 2007). Since there is a positive feedback from pleasant nature experiences on people's opinions about the environment (*e.g.* Ojala, 2009), tourism can also be expected increase the support and resource allocation for nature protection in the future.

5. Conclusions

Northern Fennoscandian studies show negative environmental and biodiversity impacts of tourism, which are seen as changes on a range from the individual to the ecosystem level. Based on the rough estimation made for northern Finland, a marginal area is under tourism and recreational use, which indicates relatively minor changes to the vegetation. Nevertheless, for sensitive wildlife species the impact area may be multiplied, especially around large tourist resorts. Tourist numbers are predicted to increase, which may enforce the direct negative impacts as well as the indirect impacts, *e.g.* through interactions with climate change. The scientific data on the species, communities and habitats provide information that can be used to prevent, minimize or restore the most negative ecological impacts of tourism.

Acknowledgments

This work was financially supported by the Finnish Forest Research Institute, Natural Resources Institute Finland, University of Oulu, European Regional Development Fund project "Socio-ecological tools for the planning of tourist destinations in Kainuu – VAAKA", and Project 283153 funded by the Academy of Finland.

References

Andersen, M., Aars, J., 2008. Short-term behavioural response of polar bears (*Ursus maritimus*) to snowmobile disturbance. Polar Biol. 31, 501–507.
Arnesen, T., 1999a. Vegetation dynamics following trampling in grassland and

heathland in Solendet nature reserve, a boreal upland area in central Norway. Nordic J. Bot. 19, 47–69.
Arnesen, T., 1999b. Vegetation dynamics following trampling in rich fen at Solendet, Central Norway; a 15 year study of recovery. Nordic J. Bot. 19, 313–327.
Ballantyne, M., Pickering, C., 2013. Tourism and recreation: a common threat to IUCN red-listed vascular plants in Europe. Biodivers. Conserv. 22, 1–18.
Balmford, A., Beresford, J., Green, J., Naidoo, R., Walpole, M., Manica, A., 2009. A global perspective on trends in nature-based tourism. PLoS Biol. 7, 1–6.
Brown, P., Driver, B., McConnell, C., 1978. The Opportunity Spectrum Concept in Outdoor Recreation Supply Inventories: Background and Application. USDA Forest Service General Technical Report RM, pp. 1–55.
Ecotourism Series 2. In: Buckley, R. (Ed.), 2004. Environmental Impacts of Ecotourism. CABI Publishing, Oxfordshire.
Chown, S.L., Huiskes, A.H.L., Gremmen, N.J.M., Lee, J.E., Terauds, A., Crosbie, K., Frenot, Y., Hughes, K.A., Imura, S., Kiefer, K., Lebouvier, M., Raymond, B., Tsujimoto, M., Ware, C., Van de Vijver, B., Bergstrom, D.M., 2012. Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. Proc. Natl. Acad. Sci. U.S.A. 109, 4938–4943.
Clark, R., Stankey, G., 1979. The recreation opportunity spectrum: a framework for planning, management, and research. USDA For. Serv. Res. Pap. PNW 1–98.
Cole, D.N., 2004. Impacts of hiking and camping on soils and vegetation: a review. In: Buckley, R. (Ed.), Environmental Impacts of Ecotourism. CABI Publishing, Oxfordshire, pp. 41–60. Ecotourism Series 2.
Cole, D.N., Landres, P.B., 1996. Threats to wilderness ecosystems: impacts and research needs. Ecol. Appl. 6, 168–184.
Coulson, S.J., 2012. The terrestrial invertebrate fauna of the Svalbard archipelago in a changing world: history of research and challenges. Can. Entomol. 145, 131–146.
Eagles, P.F.J., 2007. Global trends affecting tourism in protected areas. In: Bushell, R., Eagles, P.F.J. (Eds.), Tourism and Protected Areas: Benefits beyond Boundaries. CABI Publishing, pp. 27–43.
Eagles, P.F.J., McCool, S.F., Haynes, C.D., 2002. Sustainable Tourism in Protected Areas: Guidelines for Planning and Management. The World Conservation Union (IUCN).
Elgmork, K., 1978. Human impact on a brown bear population (*Ursus arctos* L.). Biol. Conserv. 13, 81–103.
Elgmork, K., 1983. Influence of holiday cabin concentrations on the occurrence of brown bears (*Ursus arctos* L.) in south-central Norway. Acta Zool. Fenn. 174, 161–162.
Elmendorf, S., Henry, G.H.R., Hollister, R.D., et al., 2012a. Global assessment of experimental climate warming on tundra vegetation: heterogeneity over space and time. Ecol. Lett. 15, 164–175.
Elmendorf, S., Henry, G.H.R., Hollister, R.D., et al., 2012b. Plot-scale evidence of tundra vegetation change and links to recent summer warming. Nat. Clim. Change 1465, 453–457.
Elven, R. (Ed.), 2015. Annotated Checklist of the Panarctic Flora (PAF). Vascular Plants. http://nhm2.uio.no/paf/introduction. accessed: 25.6.15.
Emanuelsson, U., 1984. Ecological Effects of Grazing and Trampling on Mountain Vegetation in Northern Sweden. Ph.D. dissertation. Department of Plant Ecology, University of Lund, Sweden.
Excursionmap.fi, 2015. URL: https://www.retkikartta.fi/. accessed 25.10.15.
Forbes, B.C., Ebersole, J.J., Strandberg, B., 2001. Anthropogenic disturbance and patch dynamics in circumpolar tundra ecosystems. Conserv. Biol. 15, 954–969.
Forbes, B.C., Monz, C.A., Tolvanen, A., 2004. Ecological impacts of tourism in terrestrial polar ecosystems. In: Buckley, R. (Ed.), Environmental Impacts of Ecotourism. CABI Publishing, Oxfordshire, pp. 155–170. Ecotourism Series 2.
Gellatly, A., Whalley, W.B., Gordon, J.E., 1986a. Footpath Deterioration in the Lyngen Peninsula, North Norway. Mt. Res. Dev. 6, 167–176.
Gellatly, A.F., Whalley, B., Gordon, J.E., Ferguson, R.I., 1986b. An observation on trampling 356 effects in North Norway: thresholds for damage. Nor. Geogr. Tidsskr. 40, 163–168.
Greller, A.M., Goldstein, M., Marcus, L., 1974. Snowmobile impact on three alpine tundra plant communities. Environ. Conserv. 1, 101–110.
Hall, C.M., Saarinen, J., 2010. Polar tourism: definitions and dimensions. Scand. J. Hosp. Tour. 10, 448–467.
Hållbar destinationsutveckling I Kiruna – Swedish Lapland, 2014 (in Swedish). http://kirunahallbardestinationsutveckling.files.wordpress.com/2013/06/fc3b6rdjupad_projektbeskrivning_hc3a5llbardestinationsutveckling_kiruna_swedishlapland_eb.pdf.
Hammit, W.E., Cole, D.N., 1998. Wildlife Recreation. Ecology and Management, second ed. John Wiley & Sons, Inc., New York.
Haukeland, J.V., 2011a. Tourism stakeholders' perceptions of national park management in Norway. J. Sustain. Tour. 19, 133–153.
Haukeland, J.V., 2011b. Ph.D. Dissertation. Sustainable Tourism Development in a Norwegian National Park Area – Exploring Social Aspects, vol. 71. Norwegian University of Life Sciences, pp. 1–46.
Heberlein, T.A., Fredman, P., Vuorio, T., 2002. Current tourism patterns in the Swedish mountain region. Mt. Res. Dev. 22, 142–149.
Heinonen, M. (Ed.), 2007. State of the Parks in Finland. Finnish Protected Areas and Their Management from 2000 to 2005. Nature Protection Publications of Metsähallitus. Series A: 170.
Helle, T., Särkelä, M., 1993. The effects of outdoor recreation on range use by semi-domesticated reindeer. Scand. J. For. Res. 8, 123–133.
Helle, T., Hallikainen, V., Särkelä, M., Haapalehto, M., Niva, A., Puoskari, J., 2012. Effects of a Holiday Resort on the distribution of semidomesticated reindeer. Ann. Zool. Fenn. 49, 23–35.
Hoogesteger, M., 1976. Changes in vegetation around the wilderness huts in Koilliskaira. Silva Fenn. 10, 40–53 (in Finnish with English summary).
Hoogesteger, M., 1984. The effect of trampling on vegetation at four cottages in Torne Lapland, northern Sweden. Rep. Kevo Subarct. Res. Stn. 19, 25–34.
Huhta, E., Sulkava, P., 2014. The impact of nature-based tourism on bird communities: a case study in Pallas-Yllästunturi national park. Environ. Manag. 53, 1005–1014.
IPCC, 2013. Climate Change 2013: the Physical Science Basis. Working Group I Contribution of to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. http://www.ipcc.ch.
IUCN, 2011. Invasive Species. https://www.iucn.org/.
Arctic Centre Reports. In: Jokimäki, J., Kaisanlahti-Jokimäki, M.L. (Eds.), 2007. Matkailualueiden kestävyyden indikaattorit. Sustainability Indicators for Tourist Resorts, vol. 52, pp. 1–80 (In Finnish with English summary).
Jokimäki, J., Kaisanlahti-Jokimäki, M.L., Huhta, E., Siikamäki, P., 2007. Bird species as indicators of environmental changes at tourist destinations. Arctic Centre Reports. In: Jokimäki, J., Kaisanlahti-Jokimäki, M.-L., Tuulentie, S., Laine, K., Uusitalo, M. (Eds.), Environment, Local Society and Sustainable Tourism, vol. 50, pp. 13–22.
Kaisanlahti-Jokimäki, M.-L., Jokimäki, J., Huhta, E., Ukkola, M., Helle, P., Ollila, T., 2008. Territory occupancy and breeding success of the Golden Eagle (*Aquila chrysaetos*) around tourist destinations in northern Finland. Ornis Fenn. 85, 2–12.
Kaisanlahti-Jokimäki, M.-L., Jokimäki, J., Huhta, E., Siikamäki, P., 2012. Impacts of seasonal small-scale urbanization on nest predation and bird assemblages at tourist destinations. In: Lepczyk, C.A., Warren, P.S. (Eds.), Urban Bird Ecology and Conservation. Studies in Avian Biology (No. 45). University of California Press, Berkeley, CA, pp. 93–110.
Kangas, K., 2009. Recreation and Tourism Induced Changes in Northern Boreal Environment. Ph.D. Dissertation. Acta Universitas Ouluensis Series A, p. 538.
Kangas, K., Sulkava, P., Koivuniemi, P., Tolvanen, A., Siikamäki, P., Norokorpi, Y., 2007. What determines the area of impact around campsites? A case study in a Finnish national park. For. Snow Landsc. Res. 81, 139–150.
Kangas, K., Tolvanen, A., Kälkäjä, T., Siikamäki, P., 2009. Ecological impacts of revegetation and management practices of ski slopes in Northern Finland. Environ. Manag. 44, 408–419.
Kangas, K., Luoto, M., Ihantola, A., Tomppo, E., Siikamäki, P., 2010. Recreation induced changes in boreal bird communities in protected areas. Ecol. Appl. 20, 1775–1786.
Kangas, K., Vuori, K.-M., Määttä-Juntunen, H., Siikamäki, P., 2012. Impacts of ski resorts on water quality of boreal lakes: a case study in northern Finland. Boreal Environ. Res. 17, 313–325.
Kelly, C.L., Pickering, C.M., Buckley, R.C., 2003. Impacts of tourism on threatened plant taxa and communities in Australia. Ecol. Manag. Restor. 4, 37–44.
Kietäväinen, A., Tuulentie, S., 2013. Tourism strategies and climate change: rhetoric at both strategic and grassroots levels about growth and sustainable development in Finland. J. Sustain. Tour. 6, 845–861.
Liddle, M., 1997. Recreation Ecology: the Ecological Impact of Outdoor Recreation and Ecotourism. Chapman & Hall, London.
Liška, J., Soldán, Z., 2004. Alien vascular plants recorded from the Barentsburg and Pyramiden settlements, Svalbard. Preslia 76, 279–290.
Lundgren, J.O.J., 1995. The tourism space penetration processes in northern Canada and Scandinavia: a comparison. In: Hall, C.M., Johnston, M.E. (Eds.), Polar Tourism: Tourism in the Arctic and Antarctic Regions. John Wiley & Sons, UK, pp. 43–61.
Lyon, K., Cottrell, S.P., Siikamäki, P., Van Marwijki, R., 2012. an Marwijk R. 2012. Biodiversity hotspots and visitor flows in Oulanka National Park. Scand. J. Hosp. Tour 11, 100–111.
Madsen, J., Tombre, I., Eide, N.E., 2009. Effects of disturbance on geese in Svalbard: implications for regulating increasing tourism. Polar Res. 28, 376–389.
Mason, P., 1998. Drafting tourist codes for the Arctic. In: Humphreys, B., Pedersen, Å.Ø., Prokosch, P., Smith, S., Stonehouse, B. (Eds.), Linking Tourism and Conservation in the Arctic, Norsk Polarinstitut Meddelelser, vol. 159, pp. 1–145.
McDougall, K.L., Morgan, J.W., Neville, G.W., Williams, R.J., 2005. Plant invasions in treeless vegetation of the Australian Alps. Perspect. Plant Ecol. Evol. Syst. 7, 159–171.
Moen, J., Fredman, P., 2007. Effects of climate change on alpine skiing in Sweden. J. Sustain. Tour. 15, 418–437.
Monz, C.A., Pickering, C.M., Hadwen, W.L., 2013. Recent advances in recreation ecology and the implications of different relationships between recreation use and ecological impacts. Front. Ecol. Environ. 2013 (11), 441–446.
Nellemann, C., Jordhøy, P., Støen, O.G., Strand, O., 2000. Cumulative impacts of tourist resorts on wild reindeer (*Rangifer tarandus tarandus*) during winter. Arctic 53, 9–17.
Nellemann, C., Vistnes, I., Jordhøy, P., Strand, O., 2001. Winter distribution of wild reindeer in relation to power lines, roads and resorts. Biol. Conserv. 101, 351–360.
Nellemann, C., Støen, O.-G., Kindberg, J., Swenson, J.E., Vistnes, I., Ericsson, G., Katajisto, J., Kaltenborn, B.P., Martin, J., Ordiz, A., 2007. Terrain use by an expanding brown bear population in relation to age, recreational resorts and human settlements. Biol. Conserv. 138, 157–165.
Nellemann, C., Vistnes, I., Jordhøy, P., Støen, O.-G., Kaltenborn, B.P., Hanssen, F., Helgesen, R., 2010. Effects of recreational cabins, trails and their removal for

restoration of reindeer winter ranges. Restor. Ecol. 18, 873–881.
Ojala, A., 2009. The interaction between emotional connectedness to nature and leisure activities in predicting ecological worldview. Umweltpsychologie 13, 10–22.
Pickering, C.M., Bear, R., Hill, W., 2007. Indirect impacts of nature-based tourism and recreation: the association between infrastructure and the diversity of exotic plants in Kosciuszko National Park, Australia. J. Ecotourism 6, 146–157.
Pickering, C.M., Hill, W., Newsome, D., Leung, Y.-F., 2010. Comparing hiking, mountain biking and horse riding impacts on vegetation and soils in Australia and the United States of America. J. Environ. Manag. 91, 551–562.
Pounder, E.J., 1985. The effects of footpath development on vegetation at the Okstindan Research Station in Arctic Norway. Biol. Conserv. 34, 273–288.
Puustinen, J., Pouta, E., Neuvonen, M., Sievänen, T., 2009. Visits to national parks and the provision of natural and man-made recreation and tourism resources. J. Ecotour 8, 18–31.
Rankin, B.L., Ballantyne, M., Pickering, C.M., 2015. Tourism and recreation listed as a threat for a wide diversity of vascular plants: a continental scale review. J. Environ. Manag. 154, 293–298.
Rey Benayas, J.M., Newton, A.C., Diaz, A., Bullock, J.M., 2009. Enhancement of biodiversity and ecosystem services by ecological restoration: a meta-analysis. Science 325, 1121–2009.
Ruth-Balaganskaya, E., Myllynen-Malinen, K., 2000. Soil nutrient status and revegetation practises of downhill skiing areas in Finnish Lapland - a case study of Mt. Ylläs. Landsc. Urban Plan. 50, 259–268.
Scott, D., Becken, S., 2014. Adapting to climate change and climate policy: progress, problems and potentials. J. Sustain. Tour. 18, 283–295.
Siikamäki, P., Kangas, K., 2009. Limits of acceptable change as a tool for protected area management – Oulanka National Park as an example. Oulanka Reports. In: Siikamäki, P. (Ed.), Research and Monitoring of Sustainability of Nature-based Tourism and Recreational Use of Nature in Oulanka and Paanajärvi National Parks, vol. 29, pp. 35–52.
Siikamäki, P., Kangas, K., Paasivaara, A., Schroderus, S., 2015. Biodiversity attracts visitors to national parks. Biodivers. Conservation. http://dx.doi.org/10.1007/s10531-015-0941-5.
Skarin, A., Danell, Ö., Bergström, R., Moen, J., 2004. Insect avoidance may override human disturbances in reindeer habitat selection. Rangifer 24, 95–103.
Skarin, A., Danell, Ö., Bergström, R., Moen, J., 2008. Summer habitat preferences of GPS-collared reindeer Rangifer tarandus tarandus. Wildl. Biol. 14, 1–15.
Stankey, G., Cole, D., Lucas, R., Petersen, M., Frissell, S., 1985. The Limits of Acceptable Change (LAC) System for Wilderness Planning. Department of Agriculture, pp. 1–37. Forest Service General Technical Report INT-176.
Støen, O.-G., Wegge, P., Heid, S., Hjeljord, O., Nellemann, C., 2010. The effect of recreational homes on willow ptarmigan (*Lagopus lagopus*) in a mountain area of Norway. Eur. J. Wildl. Res. 56, 789–795.
The Equestrian Federation of Finland, 2015. URL: http://www.ratsastus.fi/vaellusratsastus. accessed 27.10.15.
Tolvanen, A., Forbes, B., Rytkönen, K., Laine, K., 2001. Regeneration of dominant plants after short-term pedestrian trampling in subarctic plant communities. In: Wielgolaski, F.E. (Ed.), Man and the Biosphere Series: Nordic Mountain Birch Ecosystems. UNESCO, Paris, and Parthenon, pp. 361–370.
Tolvanen, A., Forbes, B., Wall, S., Norokorpi, Y., 2005. Recreation at tree line and interactions with other land-use activities. In: Wielgolaski, F.E. (Ed.), Plant Ecology, Herbivory, and Human Impact in Nordic Mountain Birch Forests. *Ecological Studies* 180. Springer-Verlag, Berlin Heidelberg, pp. 203–217.
Törn, A., Rautio, J., Norokorpi, Y., Tolvanen, A., 2006. Revegetation after short-term trampling at subalpine heath vegetation. Ann. Bot. Fenn. 43, 129–138.
Törn, A., Tolvanen, A., Norokorpi, Y., Tervo, R., Siikamäki, P., 2009. Comparing the impacts of hiking, skiing and horse riding on trail and vegetation in different types of forest. J. Environ. Manag. 90, 1427–1434.
Törn, A., Siikamäki, P., Tolvanen, A., 2010. Can horse riding induce the introduction and establishment of alien plant species through endozoochory and gap creation? Plant Ecol. 208, 235–244.
Tukiainen, H., 2010. Kuluneisuuteen vaikuttavat tekijät ja kasvillisuuden tallaushkerkkyys Oulangan kansallispuiston leiripaikoilla. Master's thesis. University of Oulu, Department of Geography, p. 95.
Tyler, N.J.C., 1991. Short-term Behavioural Responses of Svalbard Reindeer Rangifer tarandus platyrhynchus to direct provocation by a Snowmobile. Biol. Conserv. 56, 179–194.
Tyrväinen, L., Järviluoma, J., 2009. Lappi ja Suomi maailman matkailumarkkinoilla. In: Tuulentie, S. (Ed.), Turisti Tulee Kylään. Matkailukeskukset ja Lappilainen Arki. Minerva kustannus Oy. Helsinki/Jyväskylä, pp. 29–52 (In Finnish).
Tyrväinen, L., Uusitalo, M., Silvennoinen, H., Hasu, E., 2014. Towards sustainable growth in nature-based tourism destinations: clients' views of land use options in Finnish Lapland. Landsc. Urban Plan. 122, 1–15.
Ukkola, M., Helle, P., Huhta, E., Jokimäki, J., Kaisanlahti-Jokimäki, M.-L., 2007. The impacts of ski resorts on wildlife in northern Finland. Arctic Centre Reports. In: Jokimäki, J., Kaisanlahti-Jokimäki, M.-L., Tuulentie, S., Laine, K., Uusitalo, M. (Eds.), Environment, Local Society and Sustainable Tourism, vol. 50, pp. 13–22.
Uusitalo, M.T., Sarala, P., 2015. Indicators for impact management of subarctic mountain resorts: monitoring built-up areas at high altitudes in Northern Finland. Scand. J. Hosp. Tour. http://dx.doi.org/10.1080/15022250.2015.1046483.
Vistnes, I., Nellemann, C., 2001. Avoidance of cabins, roads, and power lines by reindeer during calving. J. Wildl. Manag. 65, 915–925.
Vistnes, I., Nellemann, C., Jordhøy, P., Støen, O.-G., 2008. Summer distribution of wild reindeer in relation to human activity and insect stress. Polar Biol. 31, 1307–1317.
Vuorela, J., 2014. Moottorikelkkareittien Kunnostaminen Pelkosenniemellä. B.Sc. Thesis. Oulu University of Applied Sciences, p. 25 (in Finnish).
Walker, M., Wahren, C.H., Hollister, R.D., et al., 2006. Plant community responses to experimental warming across the tundra biome. In: Proceedings of the National Academy of Sciences of the United States of America, vol. 103, pp. 1342–1346.
Wall Reinius, S., Fredman, P., 2007. Protected areas as attractions. Ann. Tour. Res. 34, 839–854.
Ware, C., Bergstrom, D.M., Müller, E., Alsos, I.G., 2012. Humans introduce viable seeds to the Arctic on footwear. Biol. Invasions 14, 567–577.
Weaver, D., 2011. Can sustainable tourism survive climate change? J. Sustain. Tour. 19, 5–15.
Wielgolaski, F.-E., 1998. Twenty-two Years of Plant Recovery after Severe Trampling by Man through Five Years in Three Vegetation Types at Hardangervidda, pp. 26–29. NTNU Vitenskapsmuseet Rapport Botanisk Serie 1998/4.
Wilderness Licences and Experiences, 2015. URL: http://www.metsa.fi/moottorikelkkailu. accessed 25.10.15.
Willard, B.E., Cooper, D.J., Forbes, B.C., 2007. Natural regeneration of alpine tundra vegetation after human trampling: a 42-year data set from Rocky Mountain National Park, Colorado, U.S.A. Arct. Antarct. Alp. Res. 39, 177–183.
Williams, R., Eschen, A., Harris, D., Djeddour, C., Pratt, R.S., Shaw, S., Varia, J., Lamontagne-Godwin, S.E., Thomas, S.T., Murphy, 2010. The Economic Cost of Invasive Non-Native Species on Great Britain. Knowledge of Life. CABI Publishing.
Ylänne, H., Stark, S., Tolvanen, A., 2015. Vegetation Shift from Deciduous to Evergreen Dwarf Shrubs in Response to Selective Herbivory Offsets Carbon Losses: Evidence from 19 years of Warming and Simulated Herbivory in the Subarctic Tundra. Global Change Biology. http://dx.doi.org/10.1111/gcb.12964.
Zachrisson, A., 2008. Who should manage protected areas in the Swedish mountain region? A survey approach to co-management. J. Environ. Manag. 87, 154–164.